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Classification modulo invariance: tangent approximations and improved face recognition

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As a first step in building a principled, geometrically informed, high-dimensional data analysis capability, we have designed a classification scheme which can approximately factor out arbitrary invariances. The scheme uses first and second derivatives of functions that describe manifolds to which classification should be invariant. We have tested the scheme on a face recognition task using free software from CSU [1] which lets us make statistically meaningful performance comparisons with existing techniques.
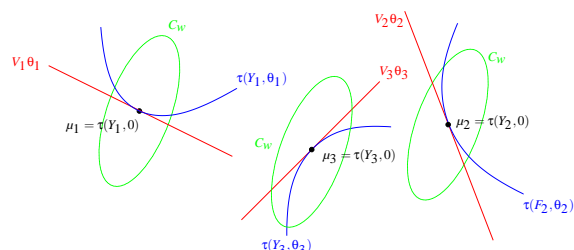
A geometrical view of our approach which improves on tangent distance methods [2] for translation, scaling, and rotation invariance. Each μ_k represents the mean of a class, the surrounding ellipses represent the pooled within-class variance C_w, which is estimated from training data. The curves τ parameterized by θ_k represent the orbits of the known transforms to which the classification should be invariant. The $V_k\theta_k$ represent tangent approximations to those orbits.

The *geometrical view* figure illustrates the intuition behind our modified within-class variance

C_k which combines the data-derived C_w and the effective variance term C_τ. We derive C_τ in a principled way from tangent approximations to the orbits (known *a priori*) by balancing the conflicting goals of de-emphasizing variations in invariant directions while remaining within the region of validity of the tangent approximation (estimated in terms of second derivatives). The results are quite good: we have the best three algorithms in comparison with the thirteen implemented in the CSU archive.
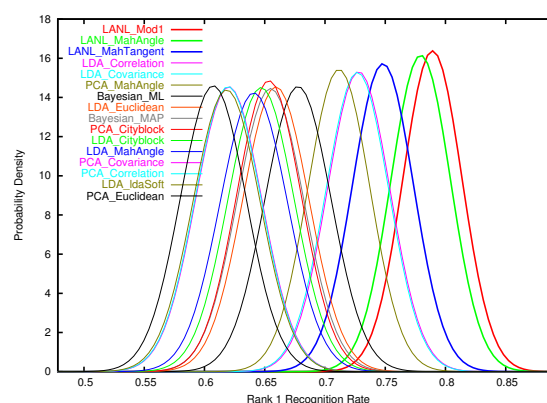
Plots of Gaussian approximations to the distributions of rank 1 recognition rates for each algorithm: note that the three best performing algorithms are variants of our approach.

The *Rank 1 comparisons* figure was constructed using the following Monte Carlo experiment. An image I_0 was chosen, followed by 160 other images, exactly one of which (I') was a different image of the individual pictured in I_0. A distance vector wass computed and the distances were used to rank the 160 images. The trial was a success if I' was the closest (rank 1) image. The fraction of successes was recorded over 160 such trials, and a histogram was constructed by repeating this entire procedure 10,000 times. The figure presented here represents Gaussian distributions fitted to these histograms.

Further details are available in a short conference proceedings article [3] and a detailed article [4] which has recently been published in a special issue of *The Journal of Computational and*

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Graphical Statistics consisting of presentations made to the National Academy of Sciences.

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